Mini-Invasive Surgery for Distal Radius Fractures: A Double Incision under 12 mm

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Abstract

Background Distal radius fracture is one of the most common lesions in adults. Surgical techniques have evolved considerably with a clear tendency toward mini-invasive techniques.

Objective Our aim is to push the limits to a 12 mm approach and evaluate its clinical and radiological results.

Patients and Methods Ten fractures in nine patients were operated by a double incision with mean size 11.50 ± 3.41 mm (range 8.00–1.00) and using a specially designed volar distal locking plate.

Results At the latest follow-up, visual analogue scale score for pain (0.20 ± 0.63 during rest and 0.60 ± 1.07 while making efforts) and quick DASH (quick Disabilities of the Arm, Shoulder and Hand) score (6.14 ± 7.43) were extremely low. All the range of motion parameters and grip strength were above the 95% barrier of the contralateral side, with exception of ulnar deviation. Radiological parameters obtained were located within the normal ranges. Time to return to independent daily tasks and work was 6.67 ± 5.15 and 10.14 ± 14.24 days, respectively. One case of transient carpal tunnel syndrome was solved with watchful waiting and one case of extensor tendons impingement was improved after plate removal. All patients were completely satisfied at the end of the treatment.

Conclusion In conclusion, mini-invasive volar technique for distal radius fractures with special designed plates in carefully selected patients allowed us to obtain good clinical and radiological results, minimal complications, fast recovery, and high-satisfactory rates.

Level of Evidence This is a Level IV, case series study.

Keywords
- distal radius fracture
- minimally invasive plate osteosynthesis
- volar plate

Distal radius fracture is a common injury affecting all age groups and one of the most common lesions treated by hand surgeons.[1,2] It poses as a public health concern due to its high incidence and economic repercussions. Temporary disability, days off work and loss of productivity triggered not only by the lesion itself but also by its imposed treatment and rehabilitation are indeed an important burden within the working population.[3]

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Surgical techniques for distal radius fractures have evolved considerably over the past decade.[4] Anterior locking plates were introduced with proven value[5] and are currently commonly used due to better reduction and fixation of these fractures than any other treatment options.[6] Volar approach has also been recognized as the gold standard to insert these plates.[5,7] However, classic Henry's approach requires extensive soft tissue stripping from the metaphyseal bone and may increase the risk of bone necrosis, nonunion or delayed healing, infection and refracture.[8] Besides, the size of the incision associated with this approach is typically not esthetically pleasing.[9]

Surgeons are developing minimally invasive approaches to reduce the surgical damage to tissues and potentially benefitting the healing.[10] Minimally invasive plate osteosynthesis (MIPO) of the distal radius was first mentioned in 2000 and 2001 by Geissler and Fernandez[11] and Duncan and Weiland.[12] During the latest years, it has become popular due to satisfactory clinical results and reduction of the complications caused by conventional treatment.[2,13] Mini-invasive techniques allow easier fracture reduction by ligamentotaxis.[1,4,9,11,14,15] Small incisions made away from the fracture site help to minimize further soft tissue injury during surgical stabilization, maintaining bone vascularity and promoting faster healing.[8,16,17] The preservation of pronator quadratus (PQ) muscle contributes also to distal radioulnar joint stability and pronation strength.[15,18] All along, they provide a more psychologically pleasant scar and a more functional one with less potential adhesions.[7]

It is considered a MIPO technique when the total length of the incision is below 30 mm[19] but currently the size of the incision has been reduced to 15 mm.[9] The ultimate restriction for minimizing size of the approach is actually the size of the implant that must be inserted. For the transverse approach, the width of the plate is paramount to decide the size of the incision. Growing interest in MIPO techniques is reflected by industry reaction toward the creation of new plate designs: smaller, simpler, and with special set ups adapted to each technique's pitfalls and benefits.

In this context, the authors wanted to push the limits to the smallest incision possible and the least invasive associated approach to take the maximum profit of the MIPO technique. We present a series of cases with less than 12-mm incision using a specific narrower plate for MIPO. Our aims are to know the viability of the surgical technique of a such limited approach and incision, to address the maintenance of the positive clinical and radiological results, and to access the potential newer complications.

Patients and Methods

Study Design

We conducted a retrospective study in patients with distal radius fractures submitted to mini-invasive approach in our center using specific plate for MIPO. Revision and approval by Ethical in Research Committee of Beneficência Portuguesa de São Paulo, São Paulo, Brazil were obtained. Between January 2018 and January 2019, 13 fractures in 12 patients were operated with this technique. Inclusion criteria were: patients between 18 and 90 years, closed injuries, no neurovascular injuries at the time of diagnosis, surgery performed in the next week following injury, follow-up greater than 6 months after surgery, and agreement to engage the study. Three of the patients refused to participate in the investigation. At the end of the study, a total of 10 fractures in nine patients were obtained. According to the *Arbeitgemeinsäft für Osteosynthesefrägen* classification, eight fractures were classified as 23-A2 and two were classified as 23-B2. Associated lesions included two ulnar fractures (patient 1 and patient 2) and one scapholunate ligament rupture (patient 9, right side).

Surgical Technique

All patients were operated under general anesthesia in supine position using the same technique and by the same surgeon. External reduction maneuvers were performed initially for the cases with more than 20 degrees of dorsal angulation and temporary K-wires were placed in case of instability of the obtained reduction (►**Fig. 1A,B**). The plate was positioned on the skin and centered mediolaterally in the radius and relatively to the fracture and joint line using fluoroscopy. An outline mark was made to define the limits of the incision and the best location for the approach (►**Fig. 2A**). A transverse incision was made to the Flexor Carpi Radialis (FCR) and approximately 15 mm proximal to the distal wrist crease (►**Fig. 2B**). Using the skin incision as a "mobile window," the subcutaneous tissue and underlying fascia were proximally and distally dissected using scissors. The FCR sheath was opened and the tendon was medially retracted to protect the median nerve and palmar cutaneous branch. The FCR tendon sheath floor was incised longitudinally and the PQ muscle was exposed. A transverse incision was made at distal portion of the PQ on the transition to volar capsule and the muscle was dissected off the periosteum using a Freer elevator from distal to proximal. Cleaning of fracture site was done. A locking anterior distal radius of anatomical form plate (45-mm

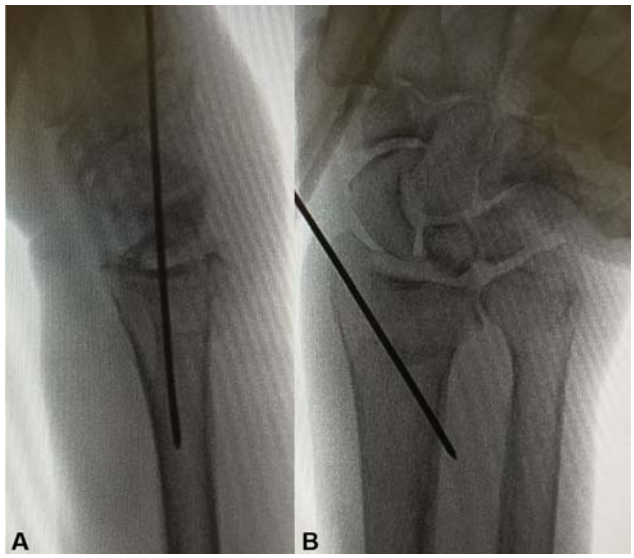

Fig. 1 Preliminary reduction of the fracture and temporary stabilization by K-wires in the lateral view (**A**) and frontal view (**B**).

Fig. 2 Planning of the transverse incision (continuous line) laterally to the FRC (dotted line) and proximally to the radial styloid (curved line) (**A**), opening of the skin (**B**), and plate insertion (**C**).

length and 16-mm width plate from GMReis, Brazil allowing three distal row screws, two proximal row screws, and three diaphyseal screws) designed specifically for transverse approach (►**Fig. 2C**), was used in all the cases. The plate was prepared by fixating the guide on its distal central orifice and then slid in a retrograde direction, with the proximal part first, underneath the PQ. Radial border was introduced first and ulnar border at the end, making sure there was no interposition of noble structures between the plate and the bone. The plate was placed just proximal to the watershed line. Frontal and lateral fluoroscopic views were obtained to control plate position until a satisfactory one. The distal central epiphyseal screw was placed using a cortical screw, allowing the most intimate contact of the plate to the distal fragment volar cortex (►**Fig. 3A**). The other four screws on the distal row were fixed using locking screws. The first cortical screw was changed for another locking one. The skin over the oblong proximal hole of the plate was marked using fluoroscopic control and a punctual incision was made over the FCR line. PQ fibers were incised and dissected with small forceps. The locking guide was fixed and a proximal cortical screw was inserted while performing light traction to recover radial length (►**Fig. 3B**). The other proximal screws were inserted, using the same punctual incision and proximal and distal skin mobilization (►**Fig. 3C, D**). No suction drainage was used. Incisions were closed by layers and skin was closed with nonabsorbable suture.

In fractures involving articular surface, arthroscopic-assisted reduction was performed using three-fourths and 6R portals. In cases of ulnar fracture (patient 1 and patient 2), a mini invasive approach (15 mm) over the lateral aspect of the ulna head between Flexor Carpi Ulnaris and Extensor Carpi Ulnaris was made, avoiding the dorsal sensory branch of the ulnar nerve. Bone fixation was done using two distal locking screw in a mini *T*-shaped plate through first incision and with three screws on the proximal fragment using 2 mini-skin incision. In cases of high suspicion of acute scapholunate dissociation, use of wrist arthroscopy was also performed. Portals used were three-fourths, 6R, mediocarpal radial, and mediocarpal ulnar. Treatment was decided according to arthroscopic findings. One case of Grade 2 scapholunate ligament instability according to Geissler's classification (patient 9, right side) was treated using dorsal capsulodesis by Mathoulin and percutaneous fixation was done with two K-wires.

Postoperative Treatment

No postoperative immobilization was used by protocol and immediate wrist movements were allowed. Cases with associated ligament lesions required 6 weeks of wrist restriction. Physical rehabilitation was prescribed on a case-by-case basis.

Outcome Measures

The collection and analysis of all the data were done by an independent investigator. Size of the incision was measure in millimeters (mm). Clinical data was accessed at the final follow-up. Visual analogue scale (VAS) for pain from 0 (no pain) to 10 (maximum pain imaginable) was applied. Global hand function was evaluated using quick Disabilities of the Arm, Shoulder and Hand (quickDASH) questionnaire validated

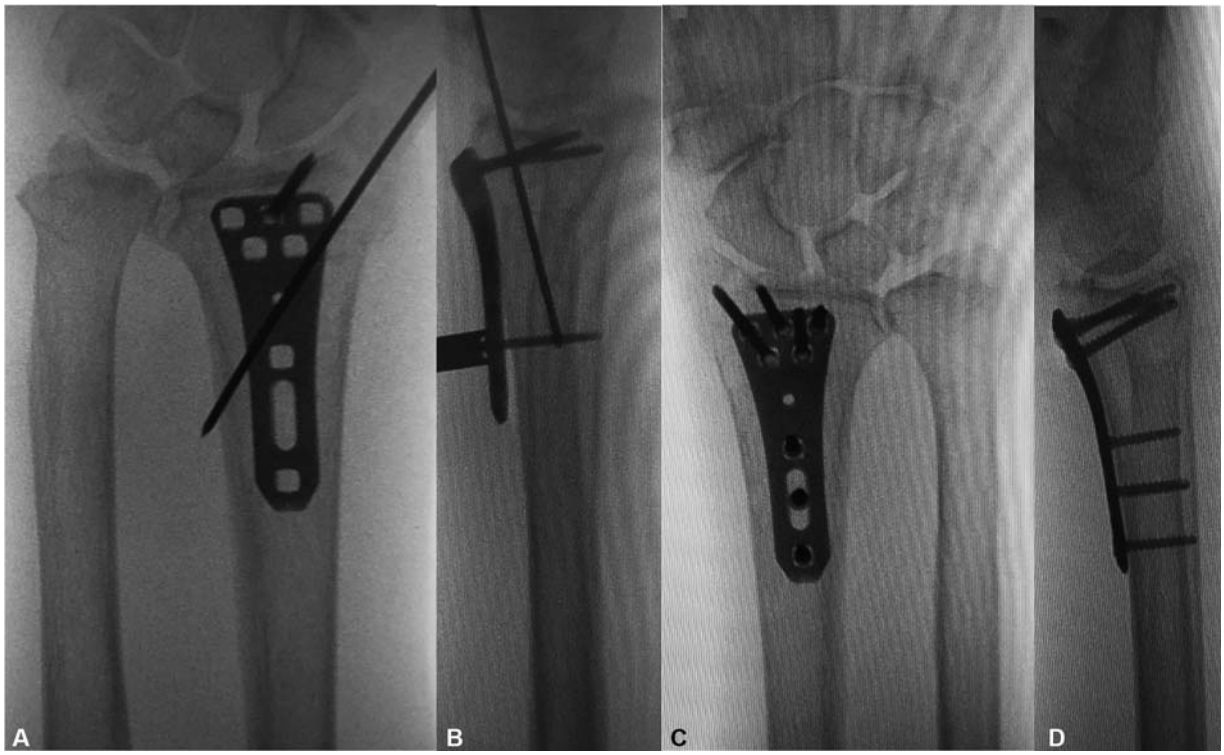

Fig. 3 Fixation of the plate with the first epiphyseal cortical screw (**A**), proximal cortical screw (**B**), and distal and proximal locking screws (**C** and **D**). At the end of the first steps, the first epiphyseal cortical screw was replaced by a locking one.

for Brazilian population from 0 (normal upper limb function) to 100 (no upper limb function). Global satisfaction with the result was graded from 0 (dissatisfied) to 5 (very satisfied). Wrist range of motion (ROM) parameters (extension, flexion, radial deviation, ulnar deviation, pronation, and supination) were evaluated with classic goniometer. Grip strength (kg) was obtained by the mean of three repeated measures with Jamar dynamometer (Sammons Preston Rolyan, Bolingbrook, IL). Radiological parameters (radial slope and radial tilt in degrees and distal ulnar variance in millimeters) were measured with plain radiographs on front and lateral views after consolidation at final follow-up. Bone union was defined as the presence of fracture healing on at least three cortices on the front and lateral radiographs of the wrist with no tenderness or pain at the fracture site. Any postoperative complications were noted.

Statistical Analysis

Quantitative variables were described as mean and standard deviation using Graph Pad Prism 8 for Windows 10. Results of ROM and grip strength are expressed in percentage of the contralateral limb function. There was no statistical analysis performed as our study was retrospective and noncomparative.

Results

We analyzed 10 fractures in nine patients (eight females and one male). In one case, there was a bilateral fracture (patient 9). Dominant side was affected in 50% of the cases. Mean age was 60.27 ± 16.03 (range 25–88) years old and mean follow-up period was 12.67 ± 4.17 (range 6.70–17.83) months. There were two cases of ipsilateral ulna fracture (patient 1 and patient 2) and one case of acute scapholunate lesion (patient 9, right side). Demographic features are displayed in ►**Table 1**.

At the latest follow-up, mean postoperative VAS score for pain was 0.20 ± 0.63 during rest and 0.60 ± 1.07 while making efforts. Mean quickDASH score was 6.14 ± 7.43. Time to resume to independent daily tasks was 6.67 ± 5.15

Table 1 Demographic features

	N	%
Patients included	9	–
Female patients	8	89%
Male patients	1	11%
Lesions included	10	–
Left sided	4	40%
Right sided	6	60%
Bilateral lesions	1	10%
Dominant side	5	50%
Associated lesions	3	–
Ulna fracture	1	33%
SL ligament injury	1	33%
	Mean	SD
Age (years old)	60.27	16.03
Follow-up (months)	12.67	4.17

Abbreviations: SL, scapholunate ligament; SD, standard deviation.

Table 2 Clinical results in detail

	VAS at rest	VAS at efforts	quickDASH	Days to IDT	Days to RW	Satisfaction	DI (mm)	PI (mm)	SI (mm)
1	0	0	6.82	5	40	5	10.00	2.00	12.00
2	0	2	9.09	3	3	5	10.00	3.00	13.00
3	2	3	25.00	15	15	5	7.00	2.00	9.00
4	0	0	0.00	7	10	5	8.00	2.00	10.00
5	0	0	4.55	1	1	5	6.00	2.00	8.00
6	0	0	6.82	5	Retired	5	7.00	2.00	9.00
7	0	1	0.00	15	1	5	9.00	2.00	11.00
8	0	0	6.82	7	Retired	5	13.00	2.00	15.00
9 right	0	0	0.00	2	1	5	8.00	11.00	19.00
9 left	0	0	2.27				7.00	2.00	9.00
Mean	**0.20**	**0.60**	**6.14**	**6.67**	**10.14**	–	8.50	3.00	11.50
SD	0.63	1.07	7.43	5.15	14.24	–	2.07	2.83	3.41

Abbreviations: DI, distal incision; IDT, independent daily tasks; PI, proximal incision; quickDASH, quick Disabilities of the Arm, Shoulder and Hand; RW, resume to work; SD, standard deviation; SI, sum of incisions; VAS, visual analogue scale for pain.

days by mean (range 1.00–15.00) and time to return to work for active patients was 10.14 ± 14.24 days by mean (range 1.00–40.00). All the patients were completely satisfied (value 5/5) with the treatment. The size of the distal transverse incision was mean of 8.50 ± 2.07 mm (range 6.00–13.00) and the size of the proximal incision was mean of 3.00 ± 2.83 mm (range 2.00–11.00). The sum of the sizes of both incisions was mean of 11.50 ± 3.41 mm (range 8.00–19.00). These results are detailed in ►**Table 2**.

Mean values for wrist ROM parameters were: extension 61.56 ± 12.72 degrees (range 38.00–82.00; $112 \pm 26\%$ of the contralateral side); flexion 57.33 ± 5.48 degrees (range 52.00–64.00; $104 \pm 21\%$ of the contralateral side); radial deviation 27.11 ± 6.41 degrees (range 20.00–40.00; $104 \pm 28\%$ of the contralateral side); ulnar deviation 23.33 ± 9.38 degrees (range 12.00–40.00; $87 \pm 20\%$ of the contralateral side); pronation 80.89 ± 6.25 degrees (range 70.00–94.00, $98 \pm 9\%$ of the contralateral side); supination 80.00 ± 5.57 degrees (range 72.00–90.00, $103 \pm 12\%$ of the contralateral side). Grip strength was by mean 25.67 ± 7.00 kg (range 17.00–39.00, $95 \pm 7\%$ of the contralateral side). Functional results are detailed in ►**Table 3**. All the fractures achieved complete bone union. At the latest follow-up, mean radiological parameters were: radial slope 21.98 ± 4.00 degrees (range 17.38–28.31); radial tilt 5.34 ± 4.90 degrees (range 0.46–15.08); distal radioulnar variance -1.55 ± 2.76 mm (range −2.15 to 0.61). Radiological results are detailed in ►**Table 4**.

One case of transient carpal tunnel syndrome was noted in the postoperative period, which was solved spontaneously until 6 months after surgery with watchful waiting (patient 7). There was one case of discomfort located on common extensor tendons of the fingers (patient 9, right side). Further investigation revealed impingement between a long screw and tendons. Plate and screws removal were performed with complete resolution of the complaints. No other complications were noted.

Discussion

Minimally invasive techniques for distal radius fractures are currently in full development.[10] Its a growing statement that these procedures lead to satisfactory clinical results[2,13] and to the reduction of the complications associated to conventional treatment.[2] Furthermore, by allowing a more esthetical scar, they also provide less potential adhesions and a more functional result.[7]

Our first aim was to access the feasibility of the surgical technique with a more limited approach. Previous literature in MIPO techniques reports an incision sized between 10 and 15 mm when using longitudinal approach,[4,7] but some papers still describe incisions within 25 and 40 mm.[9,20] For transverse approach, mean size of 19.8 mm (ranged from 17 to 26 mm) has been reported.[20] In our study, both mean size of the distal transverse incision and the sum of the sizes of both incisions (►**Table 2**; ►**Fig. 4A, B**) were indeed smaller than previously reported using the same kind of approach.

Minimizing skin incision is usually dependable on hardware size. Industry is currently developing special designed devices to adapt toward these new tendencies. However, available smaller plates have usually less distal screws or disposed in a simpler arrange. These devices are usually more suitable for extra-articular and unstable distal radius fractures than for the complex multifragmented articular ones. In fact, they do not usually cover all subchondral surface of the distal radius and may not properly stabilize all the articular fragments. In the present work, all the fractures were classified as extra-articular or partial articular fractures. Correct fixation and stabilization were achieved in all the cases, which is a major pitfall for this technique.

Our second aim was to address the maintenance of the good results of the MIPO technique using a smaller incision. In our data, both VAS score at rest and during efforts are within the lowest values when comparing with the previous

Table 3 Functional results in detail

n	Grip strength			Extension			Flexion			Radial deviation			Ulnar deviation			Pronation			Supination		
	Op. side	Ct. side	% Op. side	Op. side	Ct. side	% Op. side	Op. side	Ct. side	% Op. side	Op. side	Ct. side	% Op. side	Op. side	Ct. side	% Op. side	Op. side	Ct. side	% Op. side	Op. side	Ct. side	% Op. side
1	17.00	19.33	88	68.00	64.00	94	58.00	54.00	107	30.00	20.00	150	12.00	22.00	55	94.00	90.00	104	72.00	82.00	88
2	39.00	42.00	93	54.00	58.00	107	54.00	54.00	100	24.00	30.00	80	18.00	30.00	60	82.00	82.00	100	74.00	58.00	128
3	31.67	30.33	104	64.00	82.00	128	50.00	62.00	81	20.00	36.00	56	30.00	30.00	100	80.00	80.00	100	84.00	88.00	95
4	27.33	27.33	100	64.00	58.00	91	60.00	60.00	100	40.00	30.00	133	22.00	28.00	79	80.00	86.00	93	76.00	82.00	93
5	NA	NA	80	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	22.00	22.67	97	50.0	60.00	120	64.00	48.00	133	20.00	20.00	100	20.00	20.00	100	80.00	80.00	100	80.00	74.00	108
7	25.67	27.67	93	64.00	60.00	94	52.00	70.00	74	30.00	32.00	94	20.00	20.00	100	84.00	84.00	100	90.00	84.00	107
8	16.33	17.33	94	38.00	64.00	168	52.00	38.00	137	22.00	18.00	122	14.00	16.00	88	78.00	90.00	87	84.00	80.00	105
9 right	26.00	26.00	100	82.00	70.00	85	64.00	62.00	103	30.00	28.00	107	40.00	34.00	118	70.00	80.00	88	80.00	80.00	100
9 left	26.00	26.00	100	70.00	82.00	117	62.00	64.00	97	28.00	30.00	93	34.00	40.00	85	80.00	70.00	114	80.00	80.00	100
Mean	25.67	26.52	95	61.56	66.44	112	57.33	56.89	104	27.11	27.11	104	23.33	26.67	87	80.89	82.44	98	80.00	78.67	103
SD	7.00	7.14	7	12.72	9.58	26	5.48	9.60	21	6.41	6.25	28	9.38	7.75	20	6.25	6.15	9	5.57	8.60	12

Abbreviations: Ct, control; NA, nonavailable; Op., operated; SD, standard deviation.

encounter.[4,9] As this parameter is usually lower for studies using transverse incision rather than the longitudinal one,[17,20] this is an important data toward our preference of technique. Scores for quickDASH are also located between the lowest reported values in current literature.[4,9,20] All the ROM parameters and grip strength, with exception of ulnar deviation ($87 \pm 20\%$ of the contralateral side), were above the 95% barrier of the contralateral side (►**Fig. 5A–D**). These are extremely encouraging results. In general, they overlap previous papers relying on MIPO technique[9] and are, in fact, located above the ones that were reported using transverse incision.[20] At final follow-up, radiological parameters are all within the normal ranges. In summary, from our data, MIPO technique with smaller incisions and using a specific plate allowed good clinical and radiological results, in agreement with current literature.

One of the important advantages for MIPO technique is the fast recovery to independent daily living activities and work. Many authors have stated excellent functional recovery after MIPO with resumed work or activity around 16.2 ± 1.9 weeks,[21] especially when using PQ sparing approach.[8,20,22] In our study, time to resume to independent daily tasks and work was even lower (►**Table 2**). This fast recovery was considerably important for elderly patients, as 56% of our patients were above 65 years. Moreover, it played an important role in bilateral fractures (in one of our patients), as it provided prompt independence to daily living activities and self-care. Working and active population (44% of our patients) also took advantage from this quick return to work and the reduction of economic burden. We strongly believe these results are related to the combined advantages of MIPO approach and PQ sparing technique. All the patients were completely satisfied with the treatment. This data leads us toward this technique in every possible situation.

Only three of the patients engaged supported physiotherapy. In one case (patient 1), this recommendation was made 4 days postoperatively, according to the fears of this specific patient and not due to physical findings requiring aggressive rehabilitation. In another case (patient 6), the patient decided to begin physiotherapy by her own 15 days after surgery. The last patient also decided to undergo a physical therapy program before medical recommendation as she suffered an acute scapholunate dissociation (patient 9) and wanted to take no risks on recovery of symmetric functional results. It is important to emphasize, though, that the results for these patients were not different from the general results. No other patients needed physical therapy.

At the perioperative period, we reported one case of transient carpal tunnel syndrome (patient 7) and one case of extensor tendons impingement (patient 9, right side). This type of events are clearly noted in the current literature for MIPO.[2,9] In the first case, symptoms resumed at the final follow-up with no other gestures needed. In the second case, plate and screws removal were done with complete resolution of the symptoms. This complication was more related with technical errors in general (screw measurement) than with MIPO details specifically. No other complications were noted so far. Our follow-up period allows us to be comfortable on this matter.

Table 4 Radiological results in detail

n	Radial slope (^{0})		Radial tilt (^{0})		Radial height (mm)		Radioulnar variance (mm)	
	Op. side	Ct. side	Op. side	Ct. side	Op. side	Ct. side	Op. side	Ct. side
1	22.39	22.58	4.76	6.63	9.83	10.00	0.61	0.00
2	26.86	24.67	0.46	3.49	11.46	11.63	−1.65	−2.86
3	28.31	23.57	9.85	14.97	8.88	7.83	−8.17	−2.56
4	20.54	24.55	7.50	12.35	6.18	5.71	−3.18	−2.58
5	20.00	20.00	9.00	10.00	10.00	11.00	−0.40	−0.60
6	23.06	20.97	1.62	4.27	7.40	6.04	−0.28	−0.46
7	19.96	26.50	15.08	18.33	7.68	9.20	0.00	0.00
8	15.94	23.67	1.91	14.58	3.55	8.28	1.81	−1.36
9 right	25.32	17.38	3.22	0.00	7.96	5.89	−2.15	−2.06
9 left	17.38	25.32	0.00	3.22	5.89	7.96	−2.06	−2.15
Mean	21.98	23.31	5.34	10.58	7.88	8.71	−1.55	−1.30
SD	4.00	2.10	4.90	5.40	2.31	2.16	2.76	1.21

Abbreviations: Ct, control; NA, nonavailable; Op., operated; SD, standard deviation.

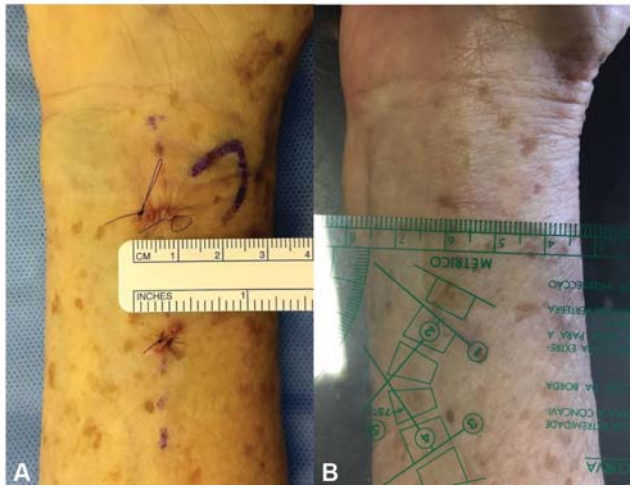

Fig. 4 Size of incisions at the day of the surgery (**A**) and at the final follow-up (**B**) measuring 9 mm for the transverse incision.

Our study has several limitations. First, it is a retrospective study. Then, as an observational study with no control group, there are no statistical comparisons. Finally, a short sample size limits the overlapping of our conclusions to general population. We should endorse a prospective study with a larger sample and longer follow-up in a near future.

In conclusion, current literature has already demonstrated that mini-invasive volar approach for distal radius fractures is a reliable and reproductible procedure. From our series, in spite of limited number of cases, we were able to obtain good clinical and radiological results and optimize the aesthetic appearance with few complications and a fast return to work and daily living. Minimizing skin incision and approach to values around 12 mm using specially designed plates (smaller and simpler than conventional volar ones) maintain the satisfactory results and bring MIPO techniques to a new stage. Careful patients' selection is,

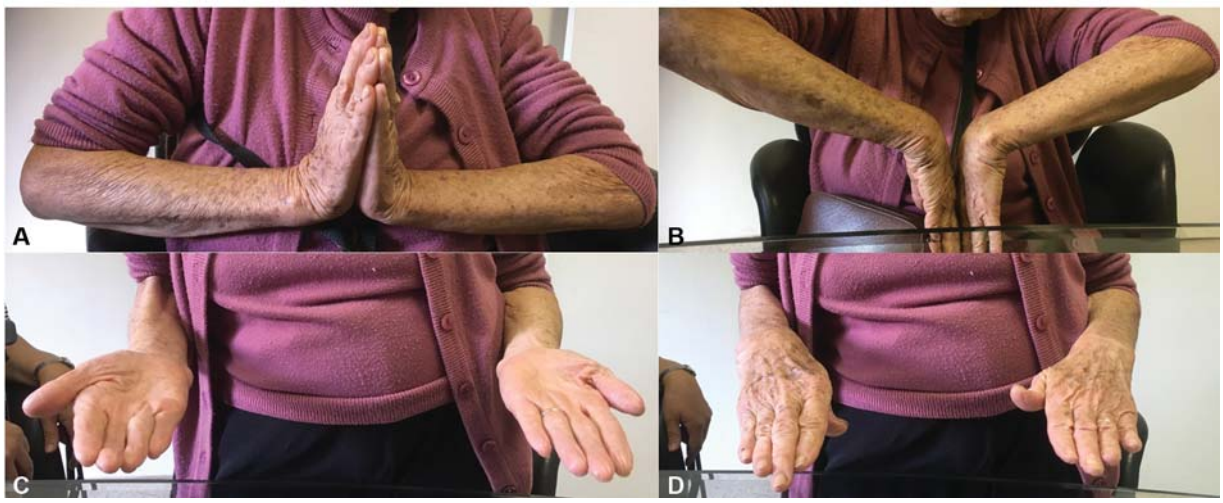

Fig. 5 Range of motion at the final follow-up for extension (**A**), flexion (**B**), supination (**C**), and pronation (**D**).

however, of seldom importance to optimize final results and avoid complications.

Note

The study was performed at Beneficência Portuguesa de São Paulo, São Paulo, Brazil.

Ethical Approval

The current study took place after revision and approval by Ethical in Research Committee of Beneficência Portuguesa de São Paulo, São Paulo, Brazil.

Conflict of Interest

None declared.

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